



Pneumatic Transfer System and Packing System for the Moon

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Topics

 **Need of Pneumatic Transfer & Packing System**

 **Concept Designs**

 **Pneumatic Transportation System**

 **Packing System**

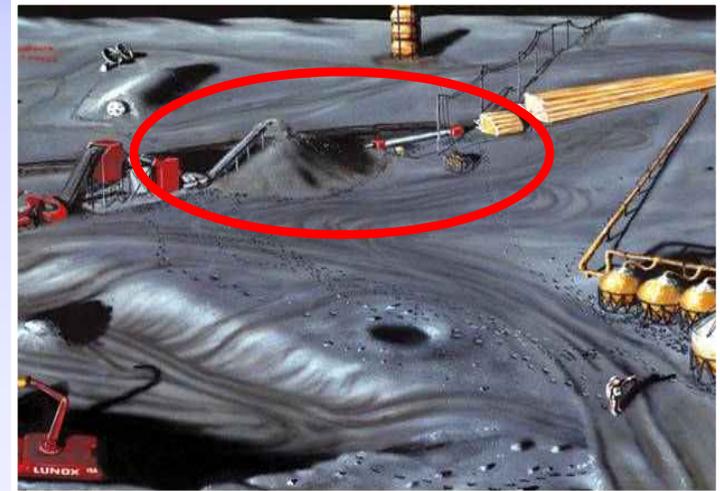
 **Future Plan**

Need of Pneumatic Transfer & Packing System

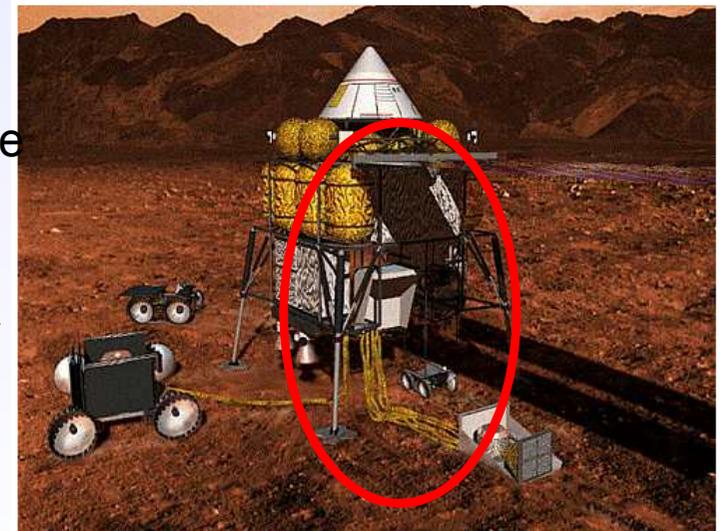
Need of Pneumatic Transportation System



➤ Vehicle makes Dust

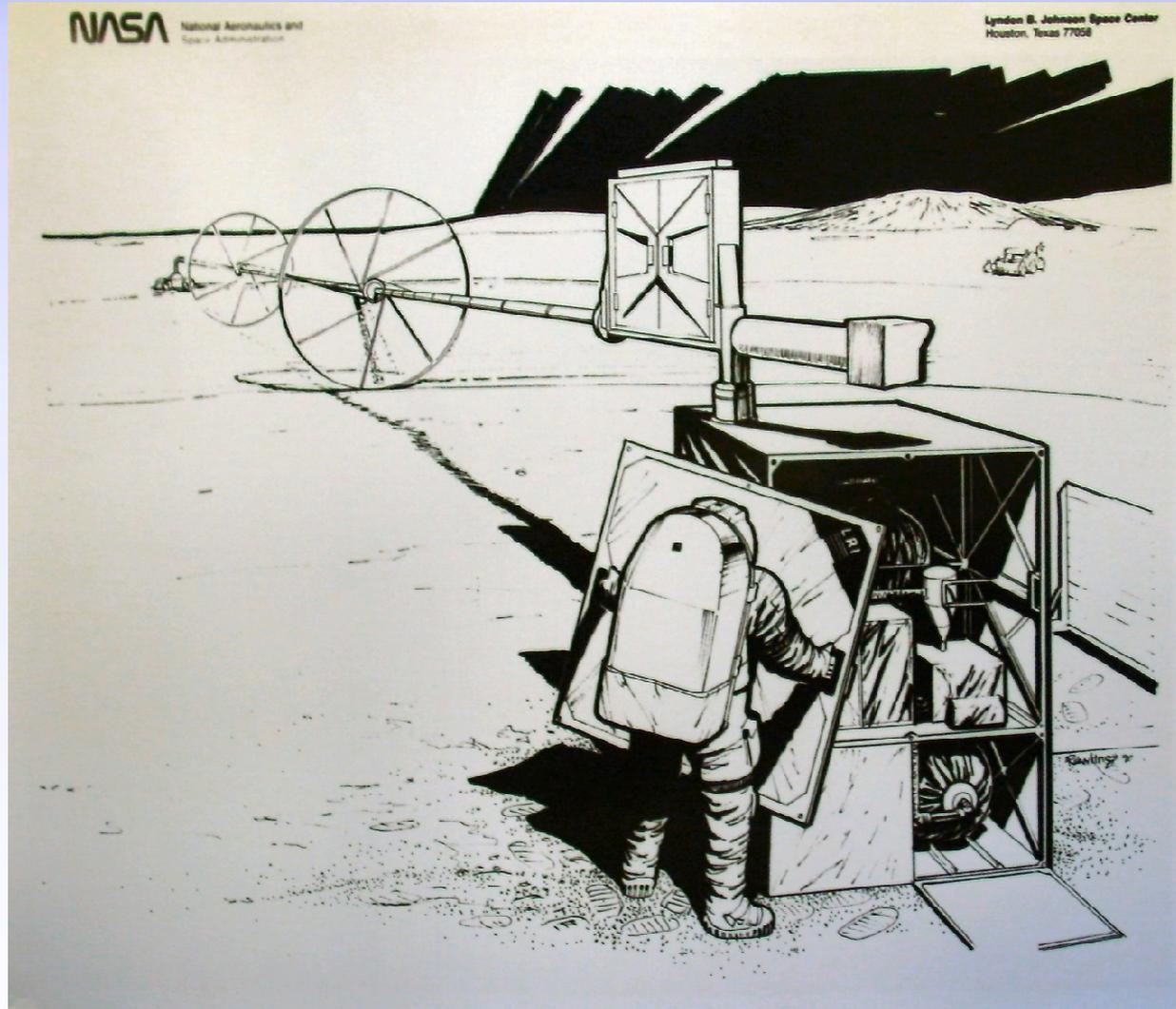


➤ Limits of transportation capacity by vehicle (depends on weight)



Need of Pneumatic Transfer & Packing System

Small pneumatic mining system which rotates in a circle and can add sections of double-wall pipe in 1 meter increments from a magazine

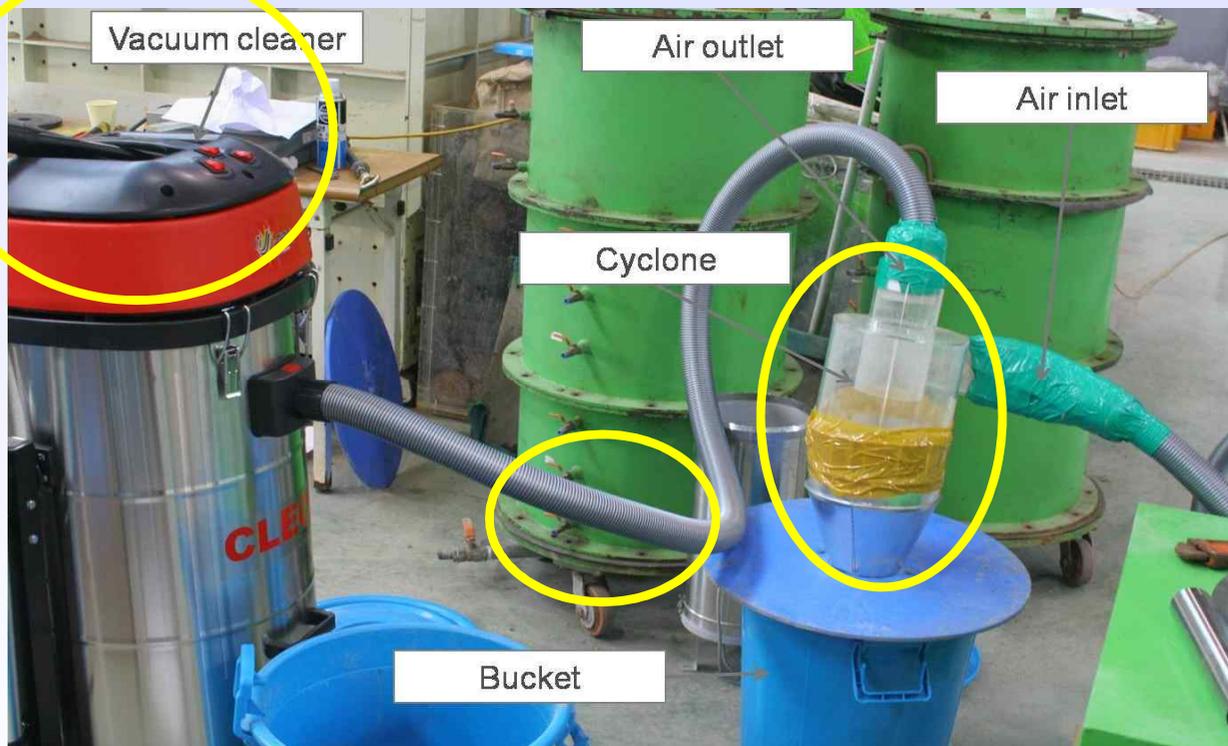


Need of Pneumatic Transfer & Packing System

○ Birth of the First Hanyang Pneumatic Transfer System

- Born to drill a borehole for lunar anchoring test
- Did not have a fancy drilling machine (things around the lab)
- Wanted do save our gold dust

➔ **We've got a nice bore hole, but.....**



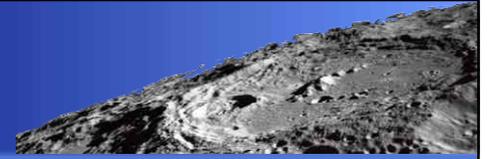
Pneumatic Transportation System



Suction Drilling

Future Goal





Pneumatic Transportation System



Concept Design

Terrestrial Pneumatic Conveying System

➤ Benefits of Pneumatic Transfer System

- Mature technology with a quite long history
- Closed pipeline against atmosphere
- Transport poisonous and hazardous materials
- Move materials vertically and horizontally



Pneumatic Conveying in the Flour Mill Facility



Prague Pneumatic Post

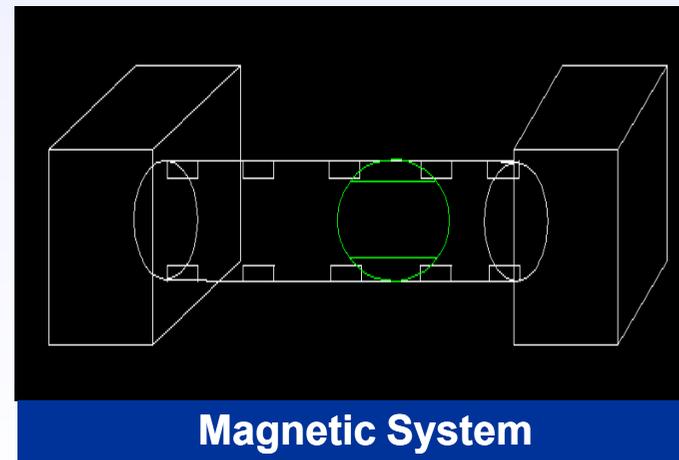
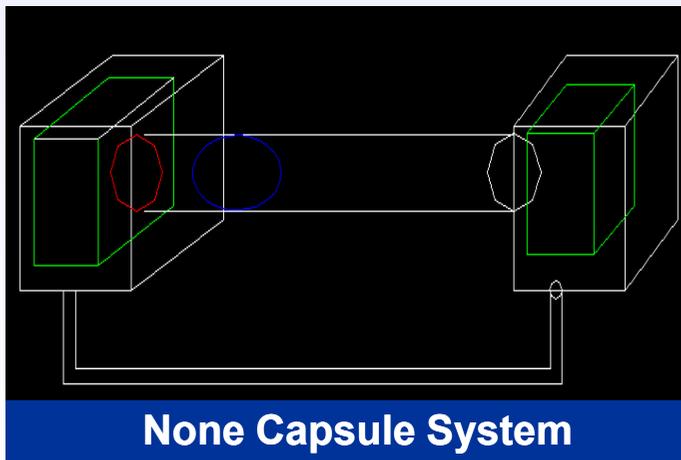
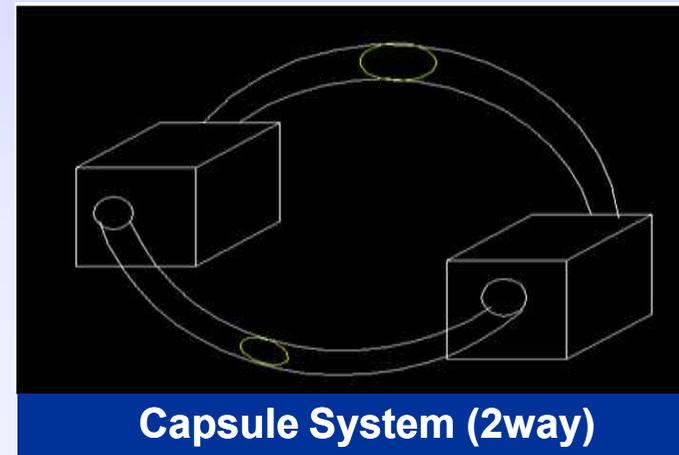
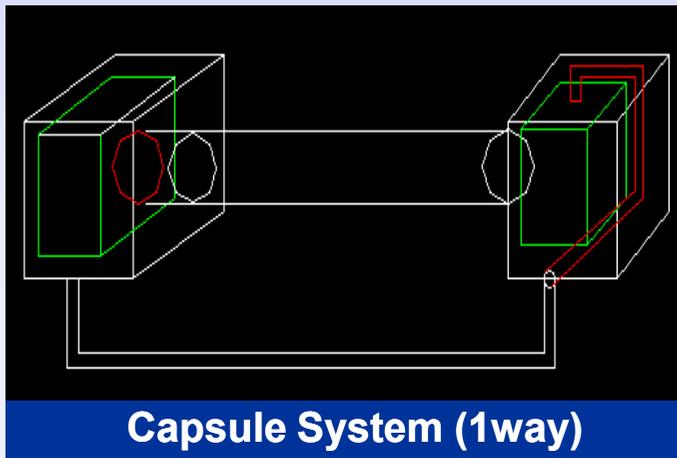
Pneumatic Tube at the Drive Through Bank



Concept Design

Several Types of Closed Pneumatic Transportation Concept

- Due to thin lunar atmosphere, PTS must recycle transfer gas
- Thus, closed system is required



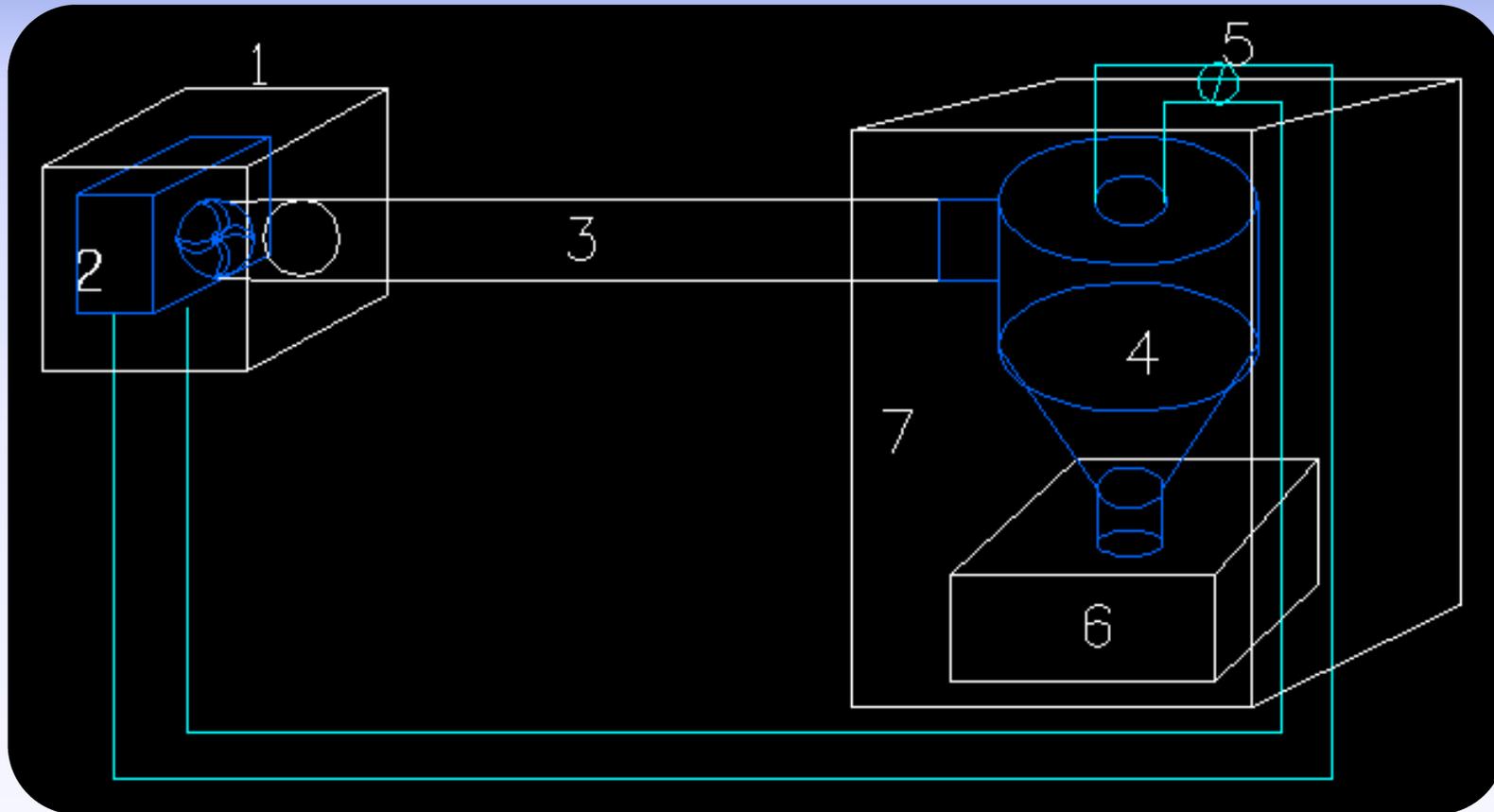
Concept Design

Concept Selection

Evaluation Criteria	Weights	Model			
		1way Capsule System	2way Capsule System	Magnet System	None Capsule System
Energy Need	20	2	2	2	3
Easy Construction	15	2	2	1	2
Automation	15	2	3	2	2
Maintenance-Repair	15	2	1	1	2
System Complexity	10	2	2	1	2
Dust control	15	2	2	2	3
Cost	10	1	2	1	2
Total	100	13	14	10	16
Final Value		1.9	2.0	1.5	2.35

Concept Design

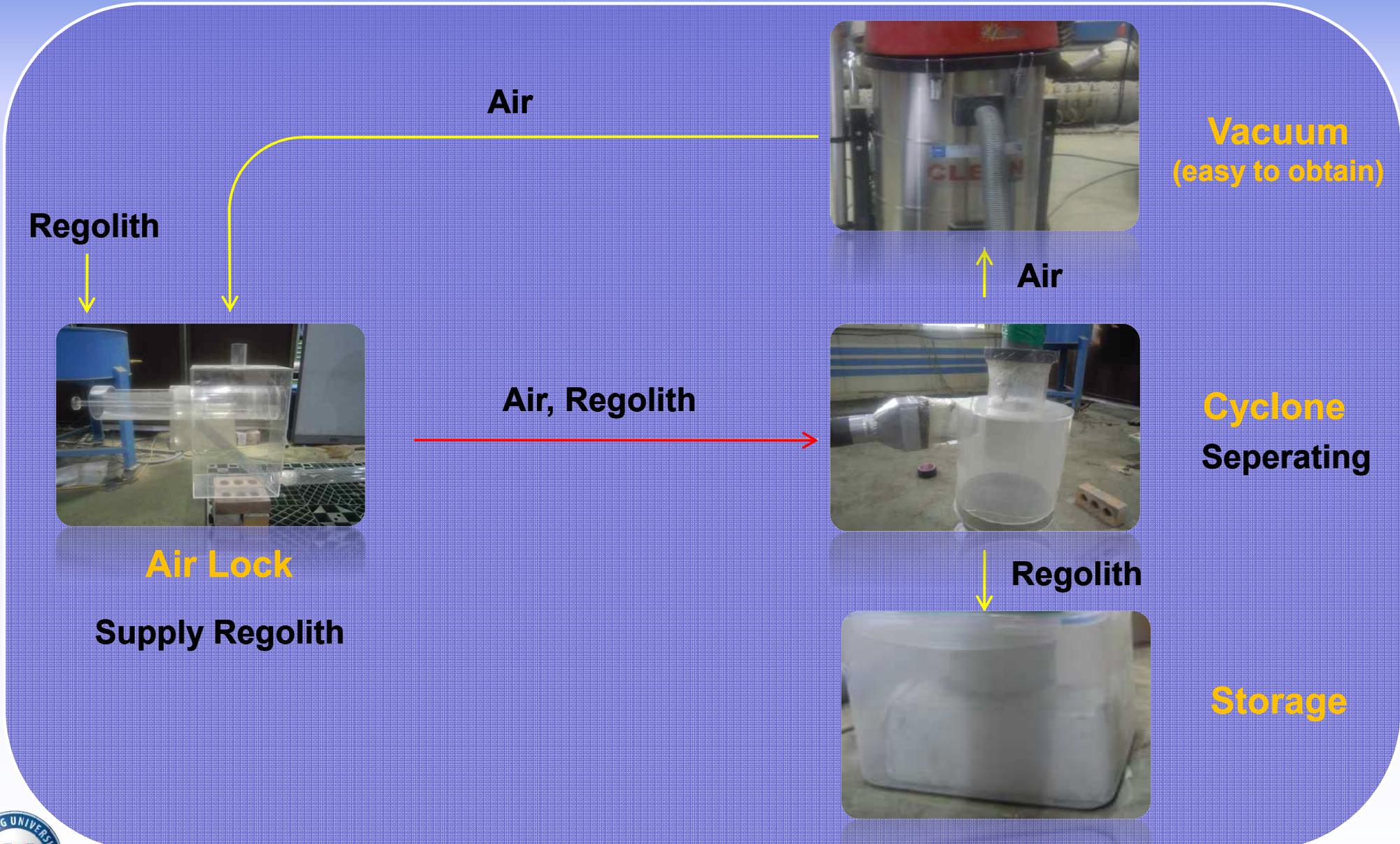
Conceptual Design of None Capsule System



1. Loading Chamber 2. Fan or Compressor 3. Pipeline
4. Cyclone 5. Filter 6. Storage 7. Supply Chamber

Concept Design

○ Preliminary Test on Pneumatic Transportation



Preliminary Test

○ Preliminary Test Factors

Diameter

- 4.4cm
- 5.5cm
- 6.7cm



Length

- 1m
- 2m



Power

- 1power
- 2power



Angle

- 0°
- 45°
- 90°



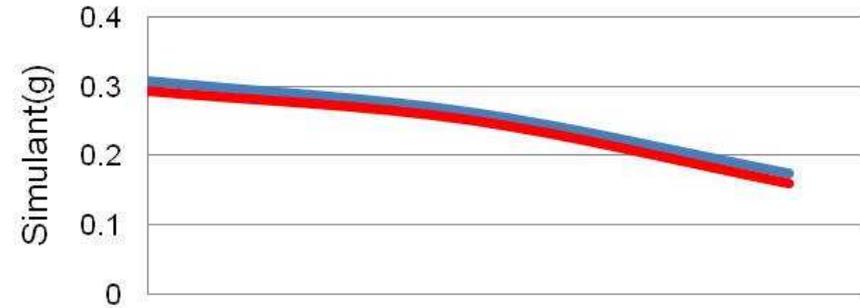
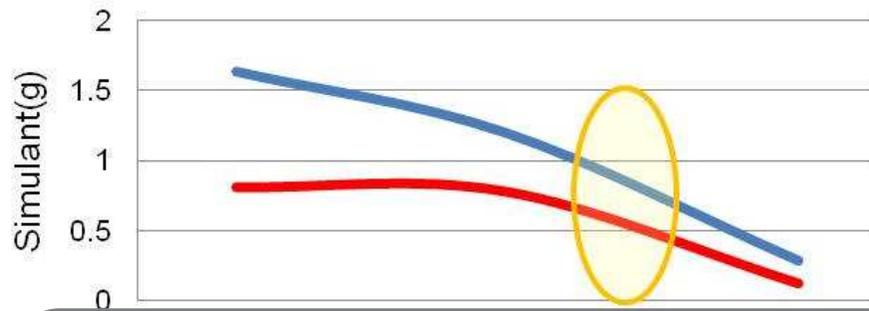
Location of Cyclone

- - 50cm
- 0cm
- +50cm

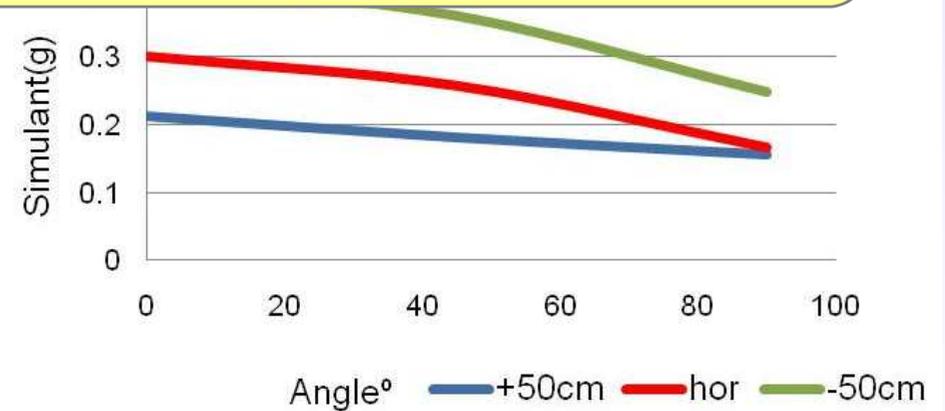
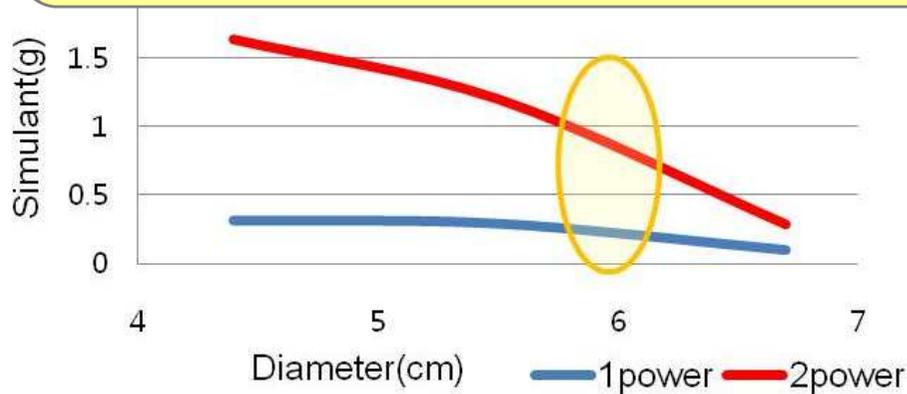


Preliminary Test

Preliminary Test Results



Velocity of the gas (particle) matters!



Prototype Development & Testing

○ Considerations

- **Blowing gas, instead of vacuum suction**
- **Moon does not have atmosphere → need to recycle gas**
- **Closed pneumatic transportation system is required**

○ Key Components



Ring Blower

Inflow Transfer
Gas into System



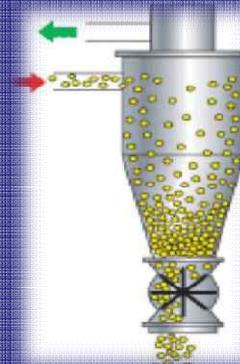
Pipeline

Transfer Mixed Flow



Feeder

Input the Transfer
Material into System



Separator

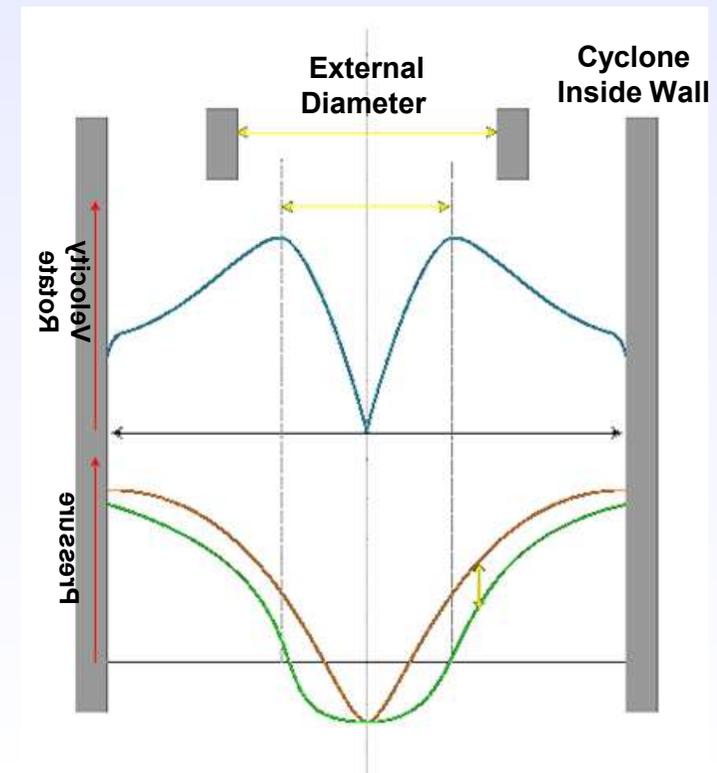
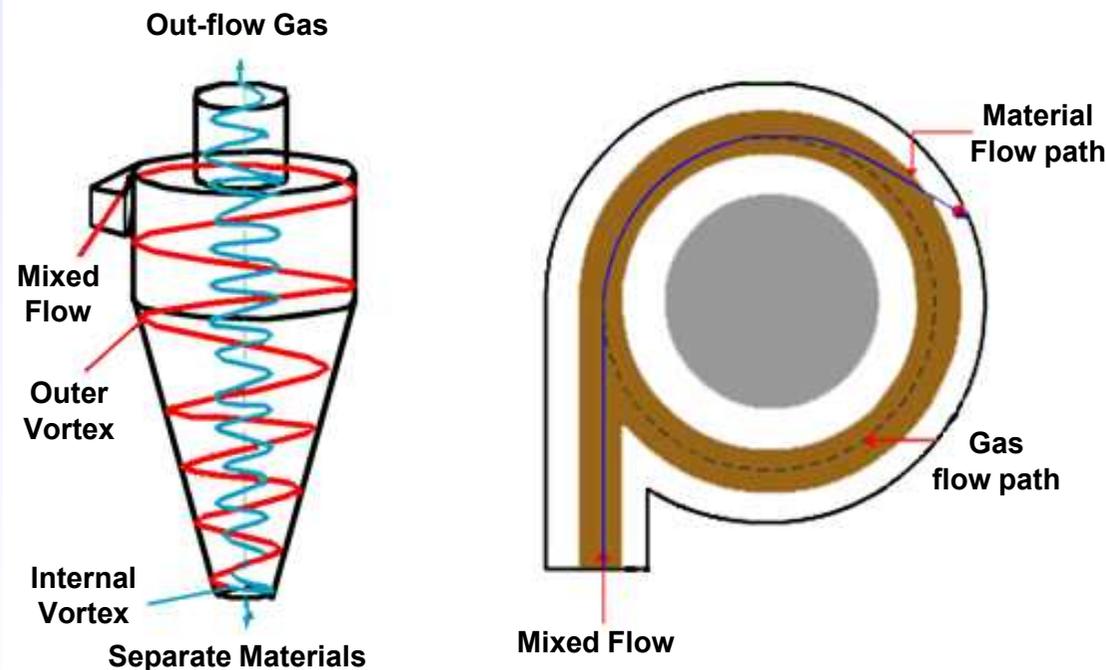
Separate transferred
gas and materials by
centrifugal force

Prototype Development & Testing

- Cyclone : most essential part for the closed system

➤ Separate transfer gas and material

- Cyclone translate linear force into centrifugal force
- Gas and Material have different density
 - ☞ Mixed flow lose their velocity and pressure, cyclone wall captures the particle
 - ☞ Speed and cyclone itself matters, rather than gravity (proper to Moon)



(Pnecon, 2011)

Pneumatic Transportation System

- Prototype of Pneumatic Transportation System



C Pneumatic Transportation System Prototype

Testing

Experiment on Material Collection Rate

Testing Condition

Running Time		1 min
Amount of Material		10Kg
Transfer Length	Blower-Feeder	1m
	Feeder-Angle Pipe	8.5m
	Vertical Pipe	1.8m
	Total Length	11.3m

Materials



Thick Particles
2mm~



Midsize Particles
0.85mm~2mm



Fine Particles
~0.85mm

Testing

- Testing



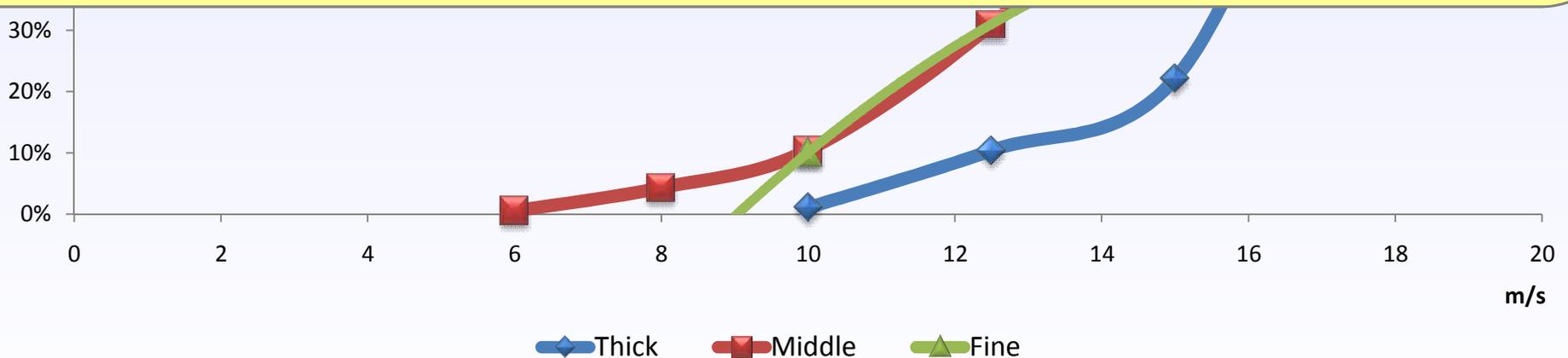
Testing

Test Results

Velocity of the gas and particle matters the efficiency

Fine Particles collection rate was only 50%

- 👉 **leaking from the joints**
- 👉 **feeder top**
- 👉 **adhesion to the pipe wall**



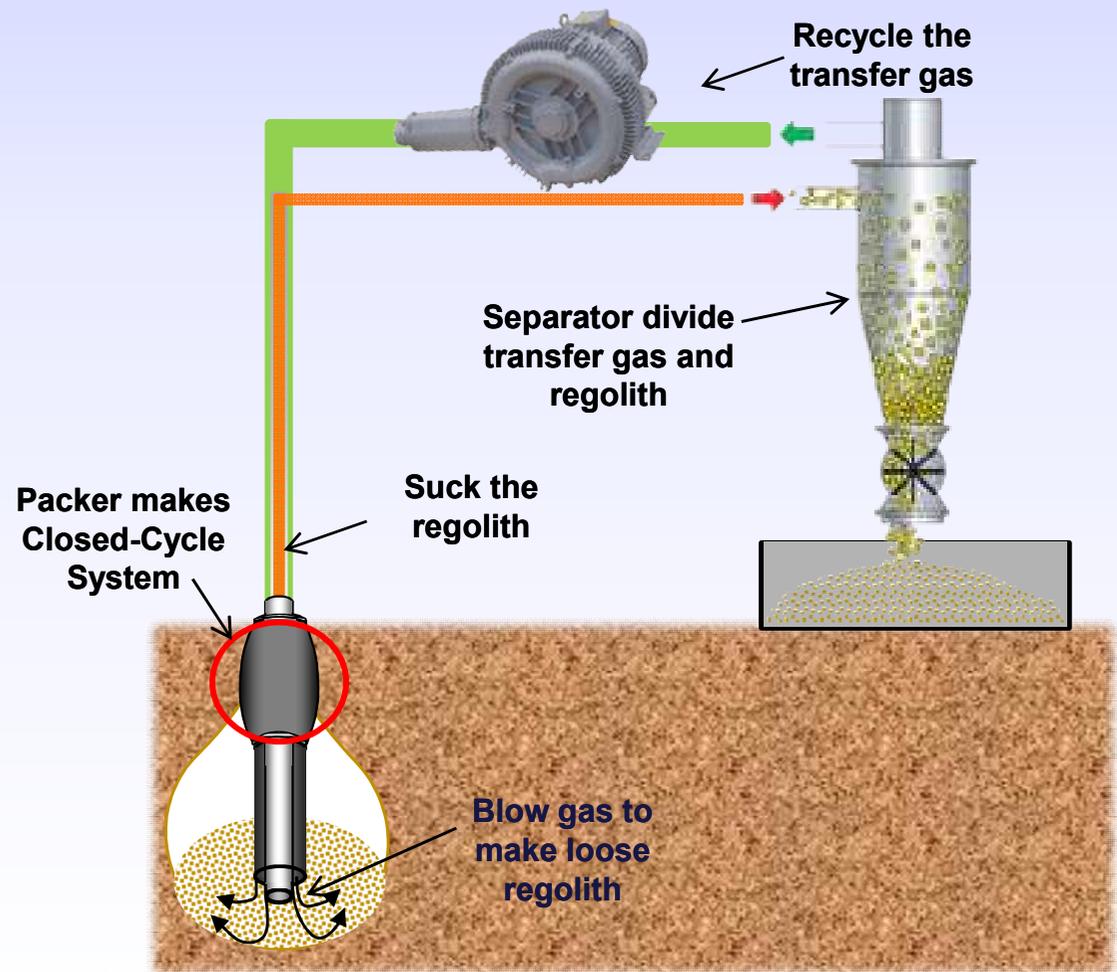
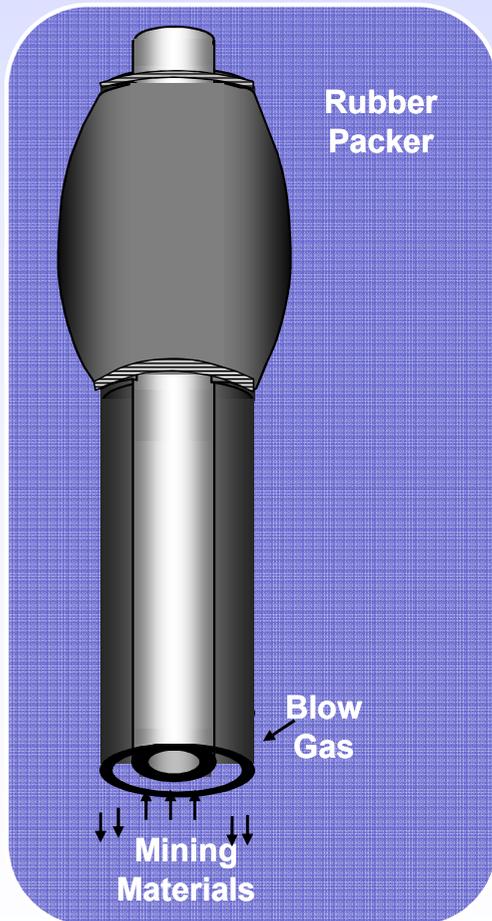


Packing System

Concept Design

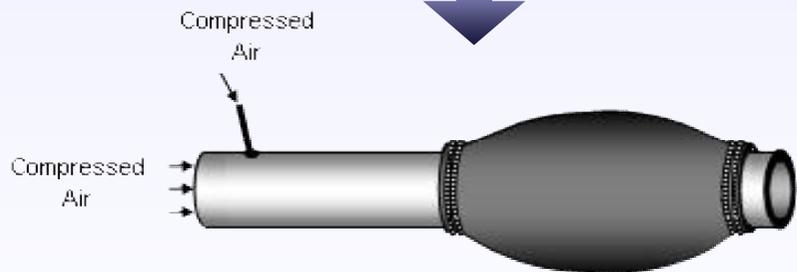
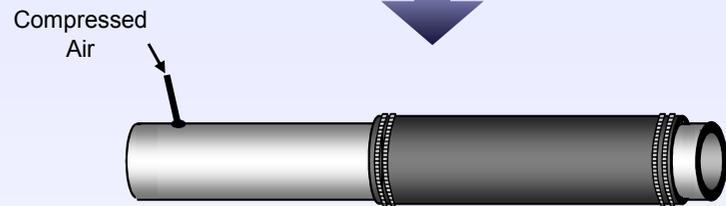
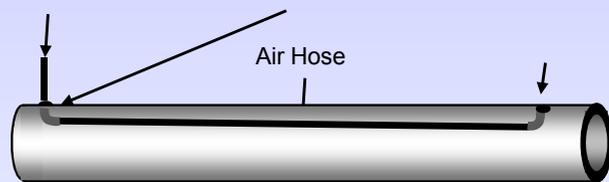
○ Packing System

- Suction Drilling needs a closed system
- Outer pipeline blow the gas, internal pipeline suck the gas and material
- **Packer has to resist at block the pressure difference**



Packing System

Design and fabrication of Packer



- Packer provide confined mining area
- Key component of Closed System

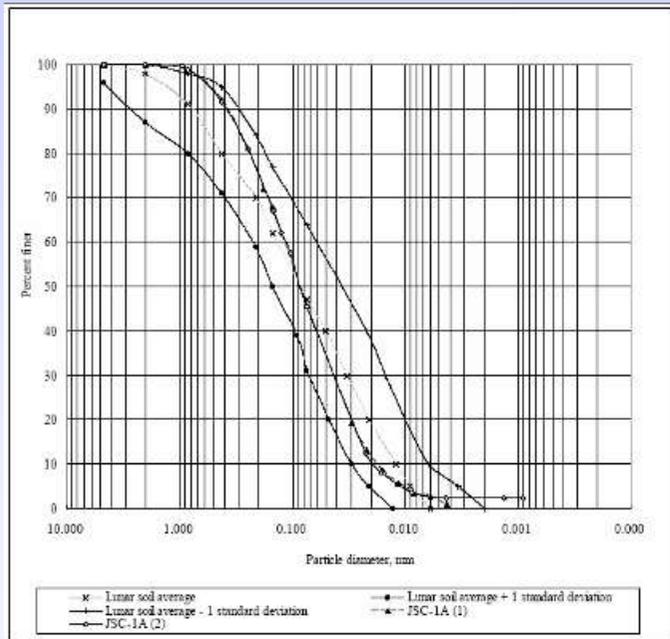


Fabricated Packing System

Feasibility Testing

Test Environment

Lunar Soil



Lunar Soil Size Distribution by Zeng et. al., 2007

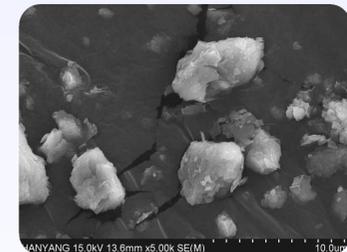
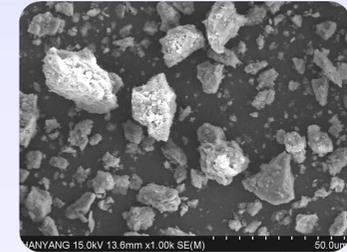
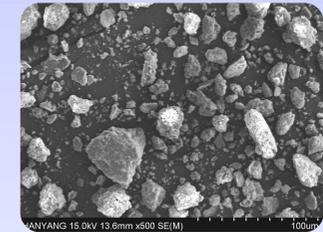
$\Phi = 30 \sim 50$ degrees (Mitchell et. al., 1972)
 $c = 0.1 \sim 1.0$ kPa (Mitchell et. al., 1972)
 $\text{SiO}_2 = 46\%$ (Average of Apollo 12 samples)

KOHLs-1

Sieve Size (#)	Percentage (%)
10	5
20	3
40	10
60	7
100	7.5
200	17.5
Pan	50
Total	100

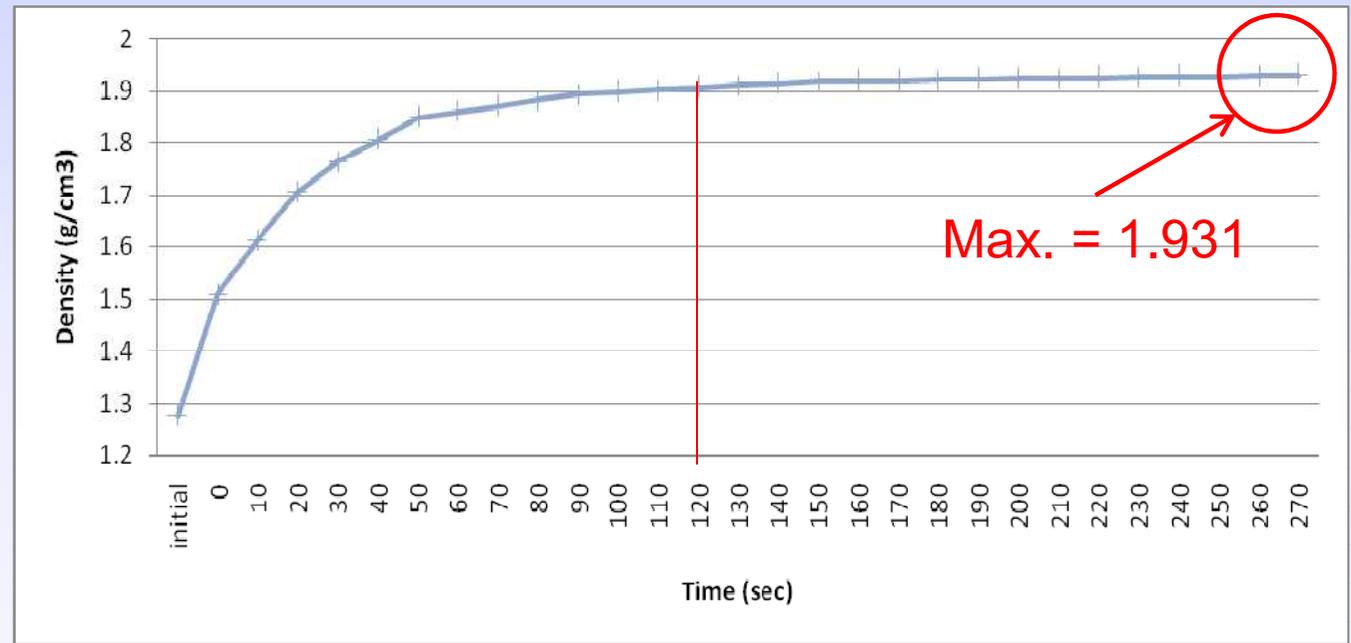
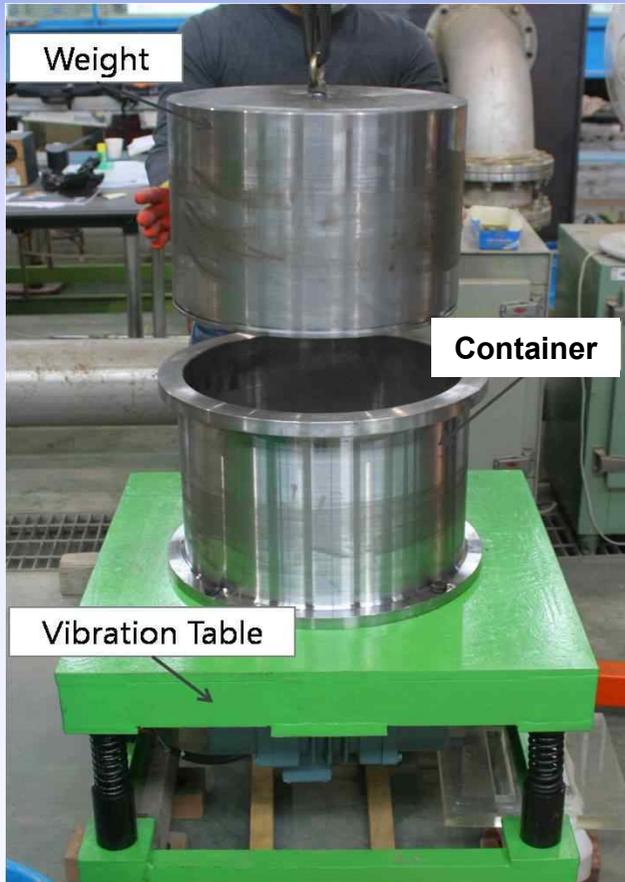
KOHLs-1 Size Distribution

Metamorphic Basalt
 $\Phi = 37$ degrees
 $c = 11.8$ kPa
 $\text{SiO}_2 = 54\%$



Feasibility Testing

Test Environment



Density Test (g/cm³)

Bulk Density = 1.7 ~ 1.9 g/cm³ (Apollo 12 sample, Carrier et. al., 1972)

Feasibility Testing

○ Packer Installation



Make the hole



Input



Set up



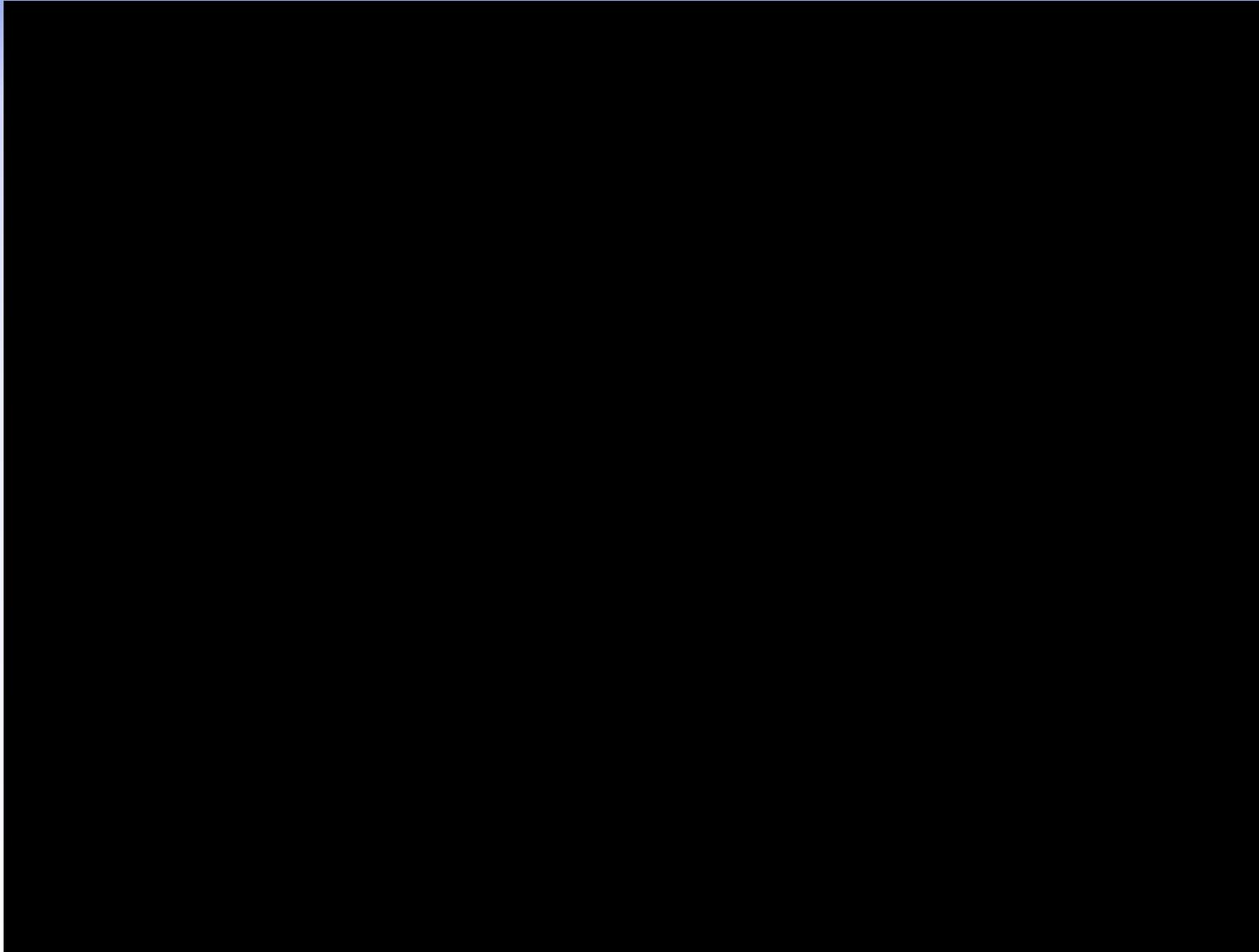
Open the valve



Explode rubber

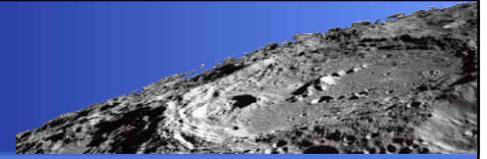
Feasibility Testing

- Testing of packer resistance to the pressure difference



Future Plan

- Merge the Pneumatic Transportation System and Packing System
- Figure out the adhesive materials on the pipe wall
- Additional Separator for the finest material (under 100micrometer)
- Experimental study for suction drilling by using packing system
- Experimental study for mining & transportation efficiency
- Effect of the Packer in the vacuum condition (leak, bearing force, etc)



Thank You!

